Collision Avoidance of multiple MAVs using a multiple Outputs to Input Saturation Technique

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retour sur innovation

Outline of the talk

I) Problem statement and Background

II) Proposed Solution

III) Experiment

I) Background and preliminaries

Collision avoidance of multiple MAVs

→ still a big issue according to:

A. Abdessameud and A. Tayebi. *Motion Coordination for VTOL Unmanned Aerial Vehicles*. Springer, 2013.

Existing solutions mainly use potential fields:

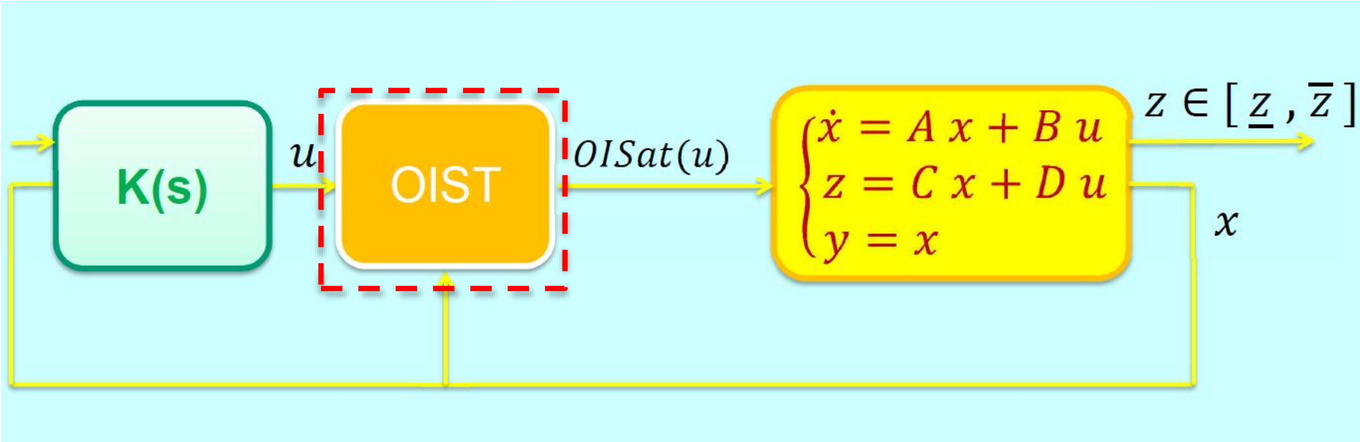
R. Olfati-Saber and R.M. Murray. Distributed cooperative control of multiple vehicle formations using structural potential functions. *FAC Proceedings Volumes*, 35(1):495 – 500, 2002. 15th IFAC World Congress.

L. Garcia-Delgado, A. Dzul, V. Santibanez, and M. Llama. Quad-rotors formation based on potential functions with obstacle avoidance. *IET Control Theory Applications*, 6(12):1787–1802, 2012.

Here, we propose a novel solution based on the OIST technique

But what is OIST ?

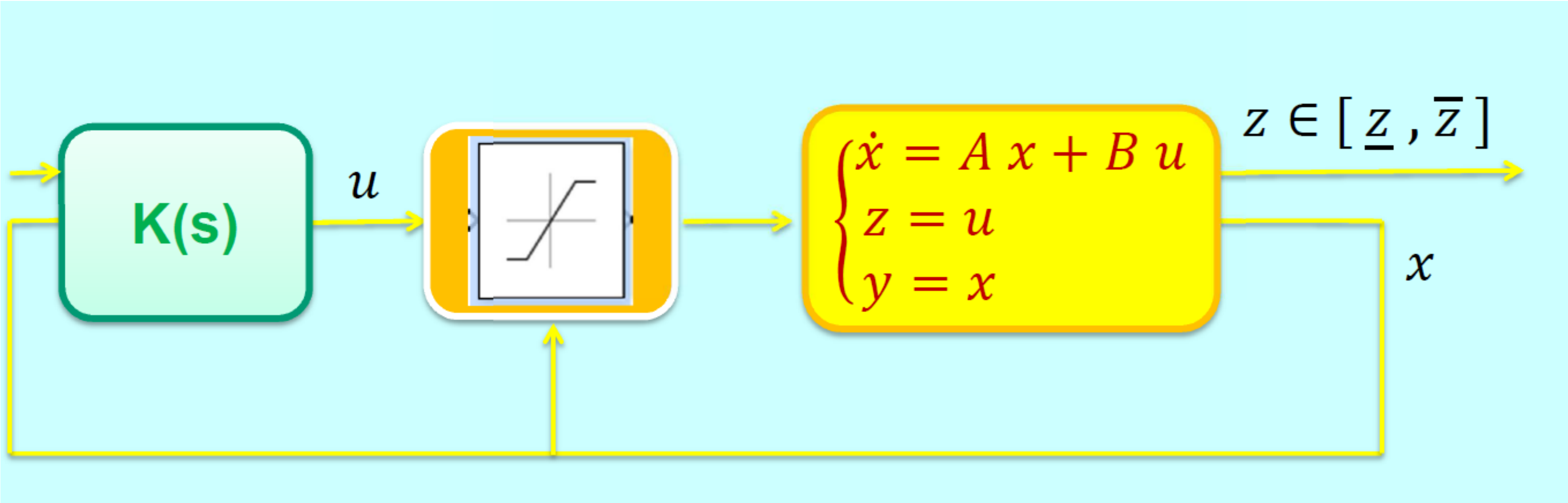
OIST : Output to Input Saturation Technique



L. Burlion. A new saturation function to convert an output constraint into an input constraint. In *Control Automation (MED), 2012 20th Mediterranean Conference on*, pages 1217–1222, 2012.

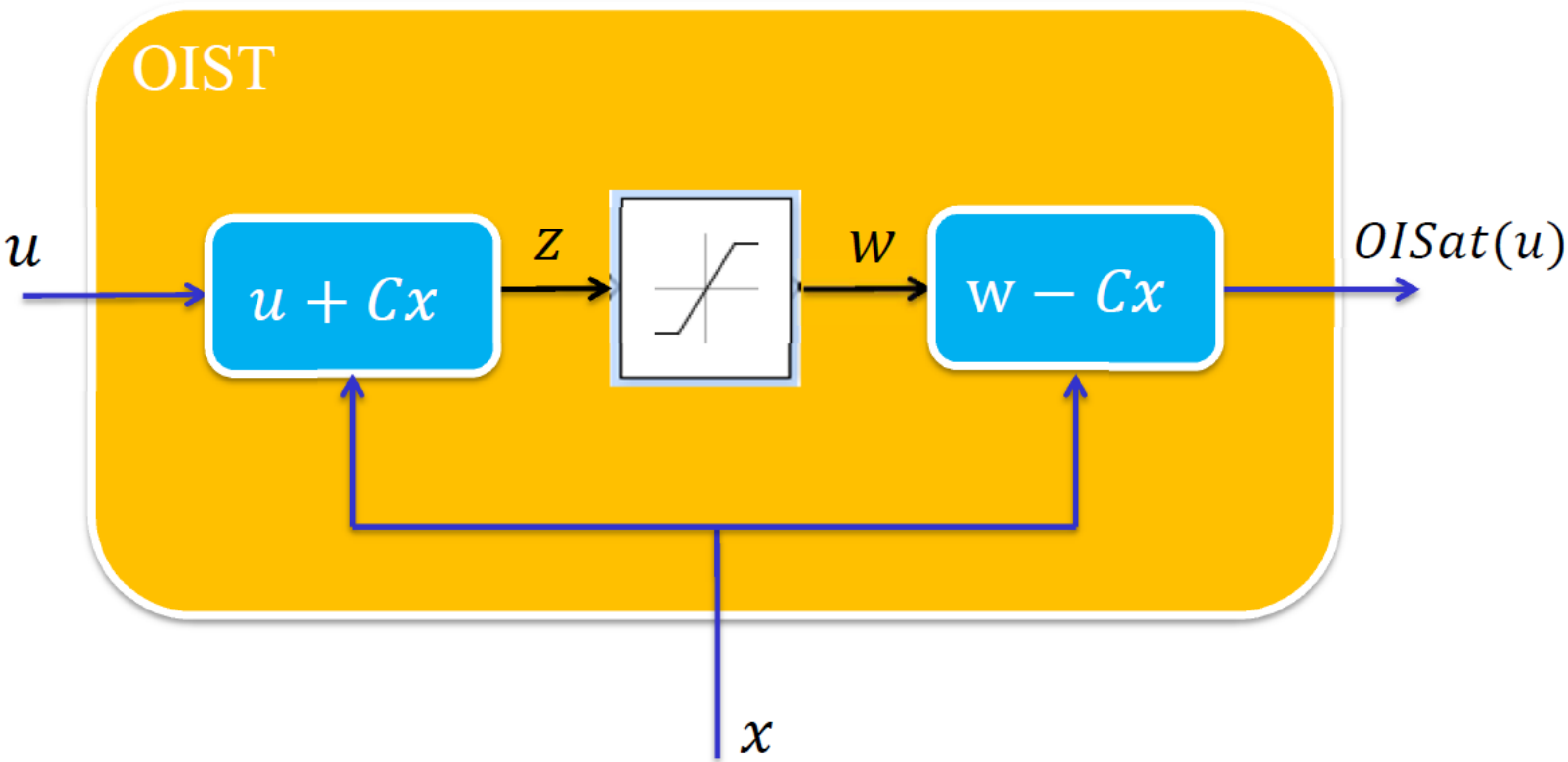
E. Chambon, L. Burlion, and P. Apkarian. Time-response shaping using output to input saturation transformation. *International Journal of Control*, to appear in 2017.

1) OIST : relative degree 0 (z = u)



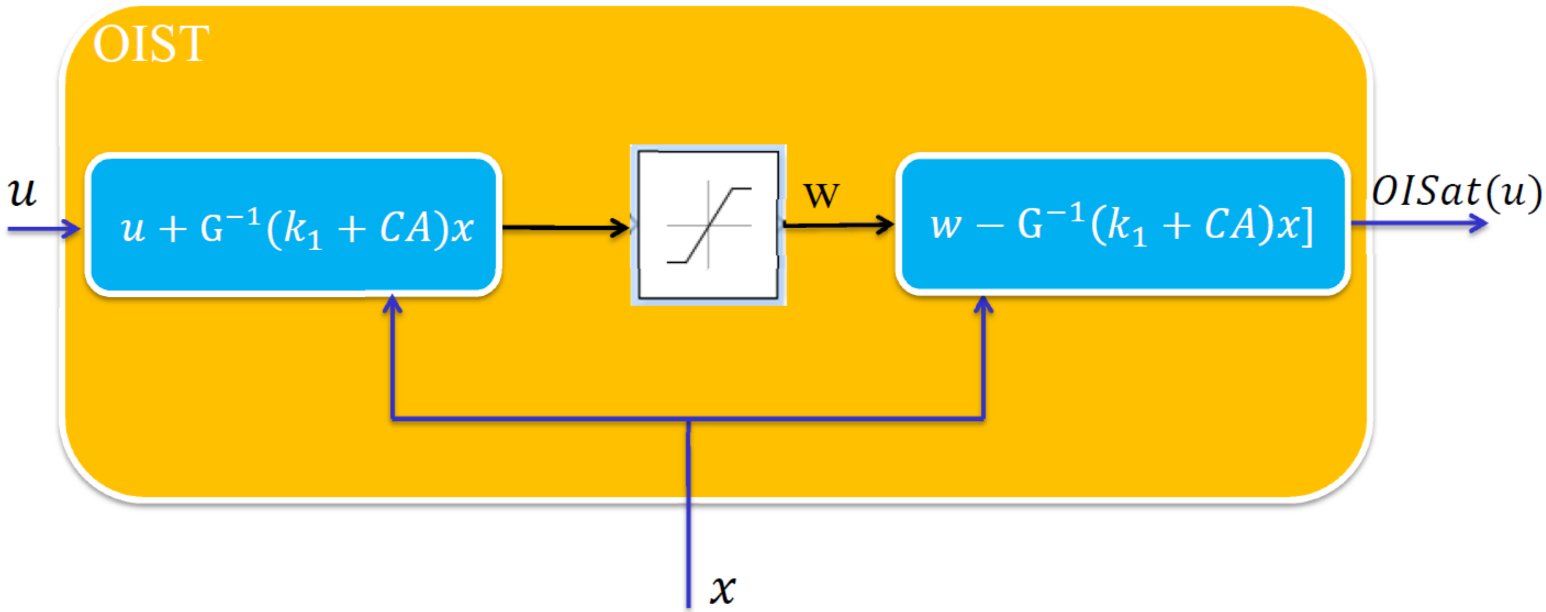
I) Background and preliminaries

2) OIST : relative degree 0 (z = Cx + u)



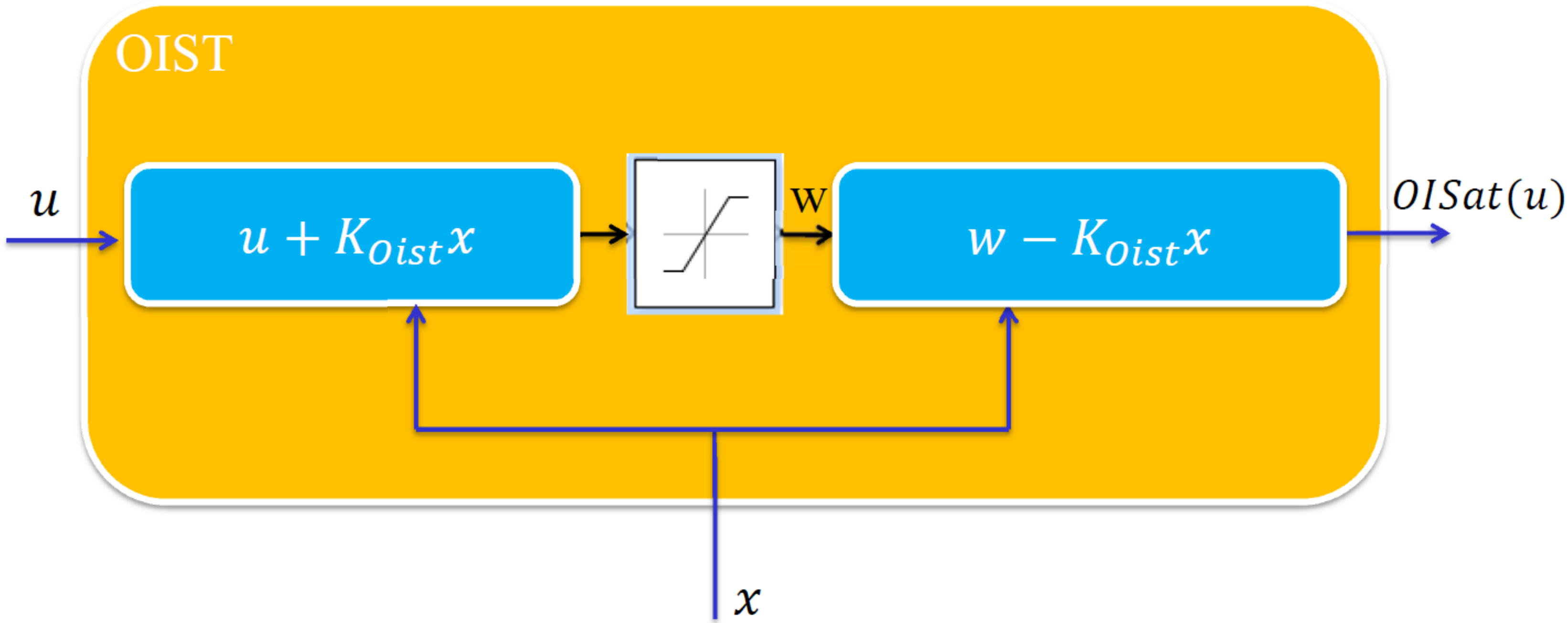
I) Background and preliminaries

3) OIST : relative degree 1 (z = Cx ; zdot = CA x + G u)



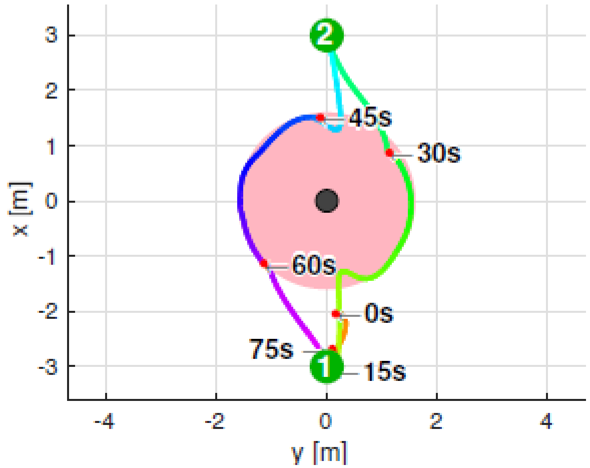
I) Background and preliminaries

4) OIST : general case



OIST was previously used for obstacle avoidance in

C. Chauffaut, F. Defay, L. Burlion, and H. de Plinval. Uav obstacle avoidance scheme using an output to input saturation transformation technique. In *2016 International Conference on Unmanned Aircraft Systems (ICUAS)*, pages 227–234, 2016.



Main features of the previous approach:

1. design a Baseline controller on each axis

$$m\ddot{\xi} + \begin{pmatrix} 0 \\ 0 \\ mg \end{pmatrix} = \mathbf{F_d} \qquad \mathbf{F_d} = m\ddot{\xi}_d + \begin{pmatrix} 0 \\ 0 \\ mg \end{pmatrix} - m\Lambda_1^2\delta_1 + \mathbf{K}_{\mathbf{r}_1}\mathbf{r}_1 + \mathbf{K}_{\mathbf{i}_1}\int_0^t \mathbf{r}_1 dt$$

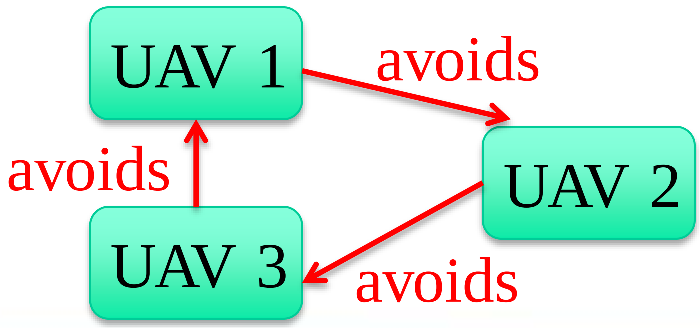
2. use the OIST methodology (relative degree 2) to constrain the distance d_o to the obstacle

$$\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} := \mathbf{M_o}(\xi)\begin{bmatrix} F_{d,x} \\ F_{d,y} \end{bmatrix} \Rightarrow \begin{bmatrix} F_{d,x}^{sat} \\ F_{d,y}^{sat} \end{bmatrix} = \mathbf{M_o}(\xi)^{-1}\begin{bmatrix} Sat_{h_1(\dot{\xi},d_o,\dot{d}_0)}^{+\infty}(u_1) \\ u_2 \end{bmatrix}$$

3. add an additional logic to avoid being stuck on the obstacle

Here, compared to our preceding result, (ICUAS 2016)

- the obstacle is now moving (since it is another UAV)
- we want to suppress « the additional simple logic » to avoid the UAV being stuck on the obstacle
- the scheme is currently limited to 3 UAVs because each UAV can only avoid one UAV



II) Proposed solution

Main features of the novel approach:

1. design a Baseline controller on each axis

$$m\ddot{\boldsymbol{\xi}} + \begin{pmatrix} 0 \\ 0 \\ mg \end{pmatrix} = \mathbf{F_d}$$

$$\mathbf{F_d} = m\ddot{\boldsymbol{\xi}}_{\boldsymbol{d}} + \begin{pmatrix} 0 \\ 0 \\ mg \end{pmatrix} - m\boldsymbol{\Lambda}_1^2\boldsymbol{\delta}_1 + \mathbf{K}_{\mathbf{r}_1}\mathbf{r}_1 + \mathbf{K}_{\mathbf{i}_1}\int_0^t \mathbf{r}_1 dt$$

2. use the OIST methodology (relative degree 2) to constrain the distance d_o to the moving obstacle

3. use also OIST to constrain the velocity to be different from 0 on the boundary of the obstacle (relative degree 1 constrained output)

II) Proposed solution

Result:

$$\begin{bmatrix} F_{d,x}^{sat} \\ F_{d,y}^{sat} \end{bmatrix} = \mathbf{M_o}(\boldsymbol{\xi})^{-1} \begin{bmatrix} Sat_{h_1(\dot{\xi},d_o,\dot{d}_0)}^{+\infty}(u_1) \\ 2Sat_{h_2(\dot{\xi},d_o,\dot{d}_0)}^{+\infty}(u_2) \end{bmatrix}$$

where

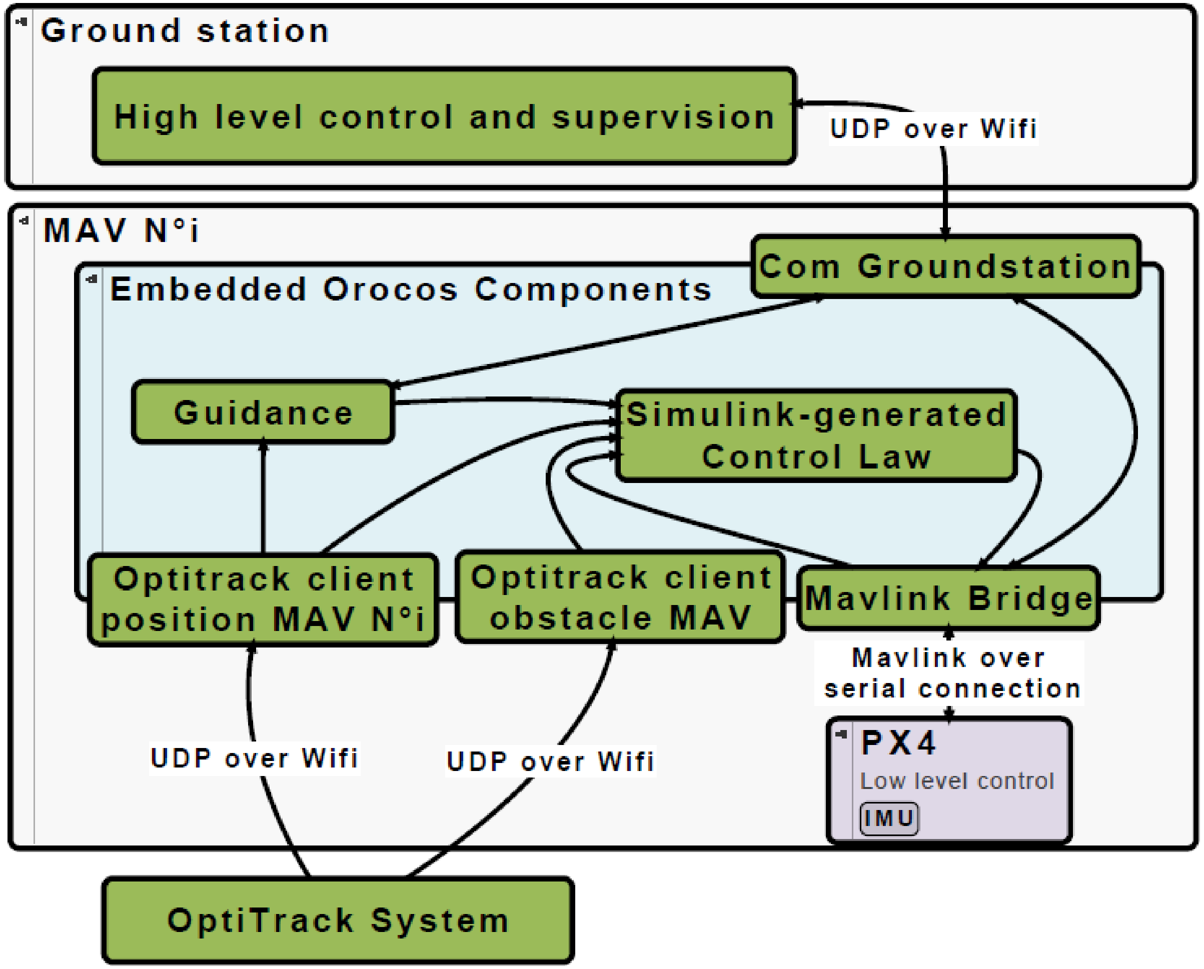
$$\begin{aligned} h_1(\dot{\boldsymbol{\xi}}, d_o, \dot{d}_0) = & -D_1 - (\kappa_1 + \kappa_2)\dot{d}_{o,2} \\ & -\kappa_1\kappa_2(d_{o,2} - d_{o,inf}^2) \\ h_2(\dot{\boldsymbol{\xi}}, d_o, \dot{d}_0) = & -D_2 - \kappa_3\dot{d}_{o,2} - \kappa_4(\phi_\perp - d_{o,inf}v_\perp^{\#}) \\ & -\kappa_3\kappa_4(d_{o,2} - d_{o,inf}^2)) \end{aligned}$$

III) Integration and experiment

3 UAVs

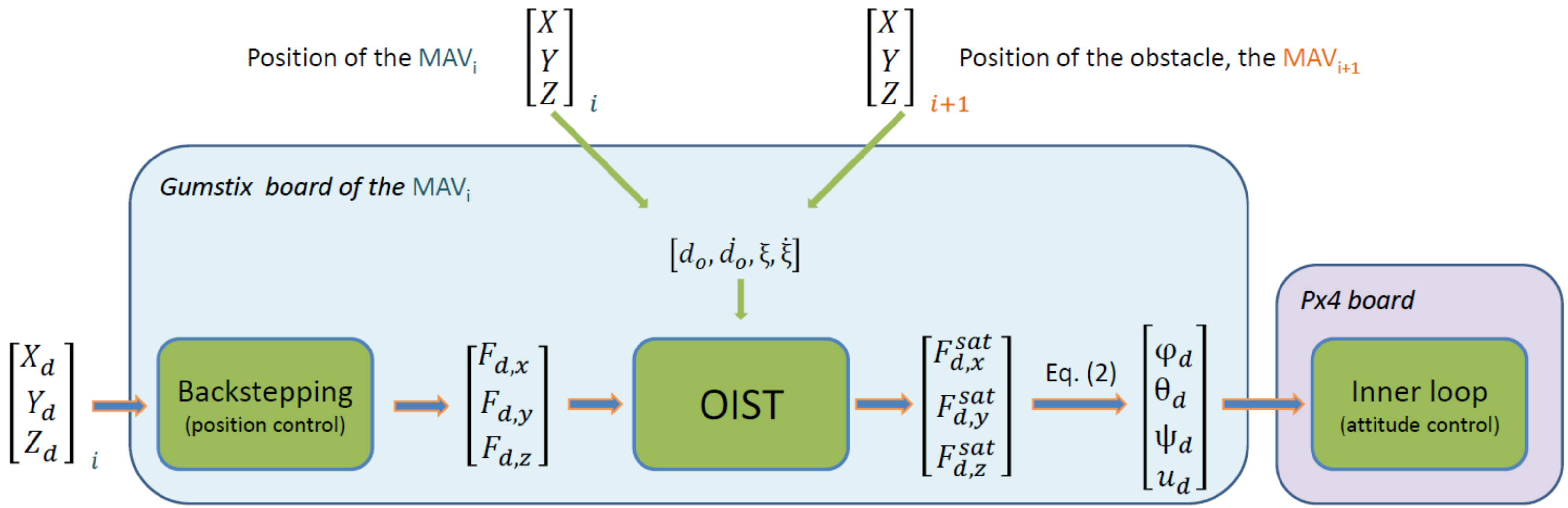
III) Integration and experiment

Framework for experimentation



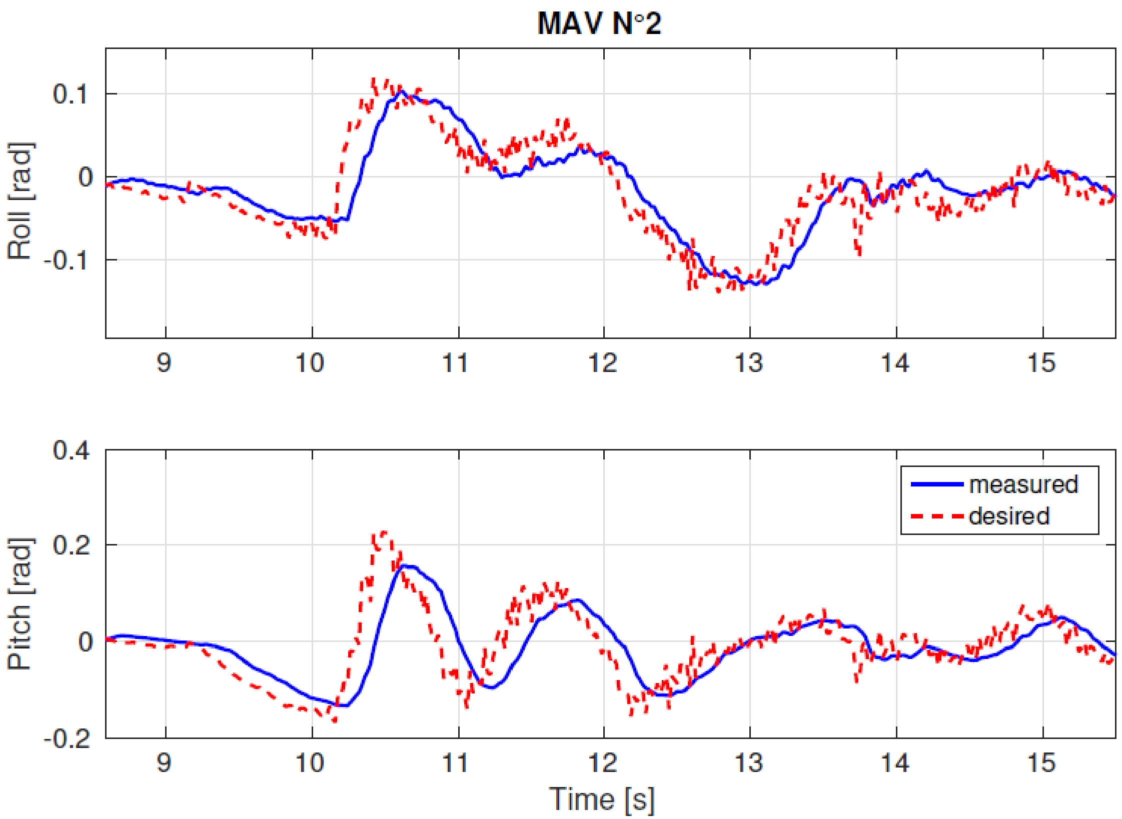
III) Integration and experiment

Guidance and control loops



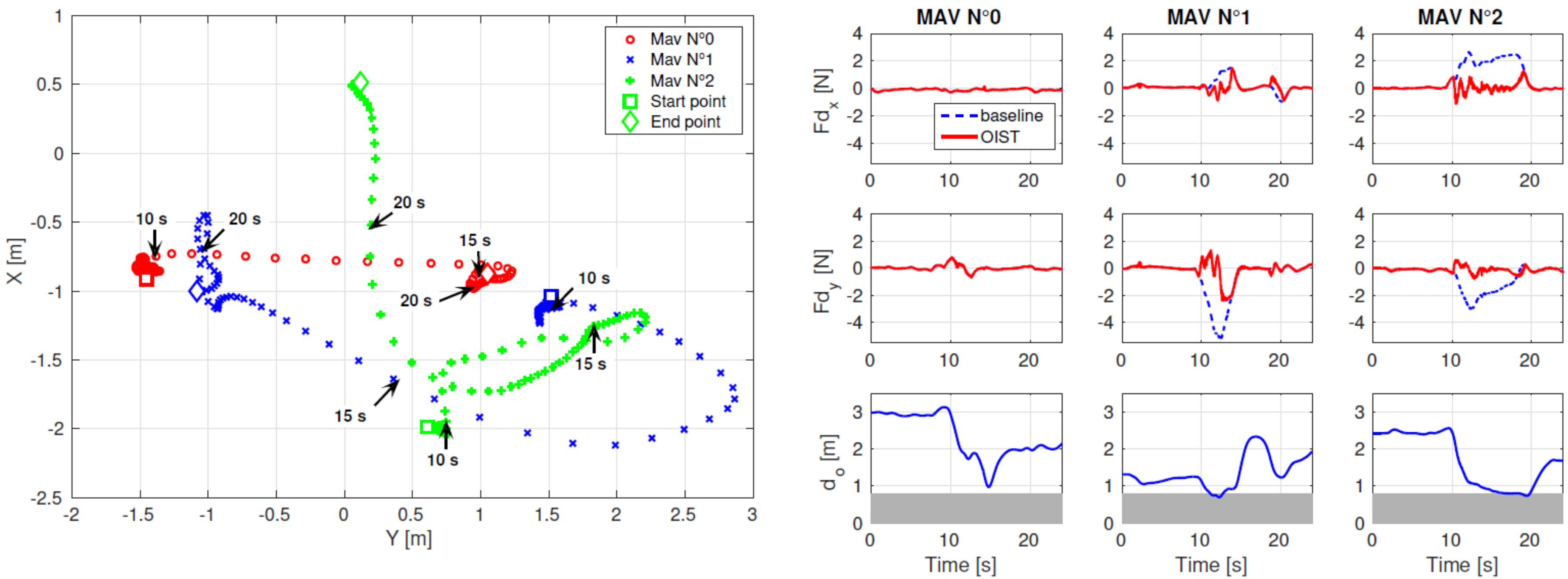
III) Integration and experiment

Inner Loops (experimental results)



III) Integration and experiment

Guidance (experimental results)



III) Integration and experiment

Guidance (experimental results)

VIDEO

Conclusions

We proposed a novel guidance solution based on OIST to avoid a moving obstacle.

Such a solution was applied to the formation flight of 3 MAVs

Experimental results support the newly proposed methodology

Stability proofs were not provided here but are in good progress

The end

Thank you for your attention !

For any further questions regarding:

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